

HAND-HELD LIGHT THERAPY APPARATUS AND METHOD

FIELD

[0001] This application relates to light therapy apparatus and methods. More particularly, this application concerns apparatus and methods for delivering light to a subject's eyes to provide circadian rhythm adjustments, and treat seasonal affective disorder and other disorders or problems that can be effectively treated with light therapy.

RELATED APPLICATION

[0002] This application claims the priority of provisional application number 60/476,574 filed June 6, 2003.

BACKGROUND

[0003] Light therapy systems have been widely used for some time to treat circadian rhythm disorders, seasonal affective disorder and other such problems by delivering light through the eyes of a subject. One problem has been the need to provide the necessary light intensity and color spectrum, similar to daylight. In many cases fluorescent lights are used because they tend to provide an effective spectrum of light and are longer lasting than incandescent lamps. However, the high intensities of light needed for such treatments required relatively large-sized lamps and other components. Thus, many commercial light therapy units have been large, bulky and cumbersome.

[0004] In the last decade, advances in ballast and fluorescent light technology have allowed some companies to produce smaller, lighter-weight light therapy units. An example is shown in U.S. Patent No. 6,488,698 (Hyman). Such units, though smaller and less cumbersome than previously mentioned designs, are usually too large to be hand-held. Further, the Hyman device has no display or other means to convey information.

[0005] Some products have been made portable by developing wearable devices which bring the light source close enough to the subject's

eyes to achieve the effective high-intensity lux output. These units typically incorporate smaller, less intense lamps that can be battery powered. Examples are shown in U.S. Patents Nos. 5,447,528 (Geraldo); 6,350,275 (Vreman et al.); and 6,053,936 (Koyama et al.).

[0006] Such devices tend to flood the user's field of vision with light. This makes it difficult for the user to look past the bright light source to more dimly lit surfaces to accomplish daily tasks. This arrangement can cause eyestrain, headache and other discomforts.

[0007] Another approach involves using LEDs to try to make portable devices. However, prior art LED ocular devices tend to be harsh to the eyes and create retinal after imaging. Prior art LED devices are of limited portability because of power consumption that requires access to an external power outlet or relatively large cumbersome batteries, rather than using a portable or built-in battery pack.

[0008] Some products have addressed the portability and eyestrain problems by developing devices worn against the skin. These non-ocular approaches radiate light energy through the skin to the blood stream. Examples are shown in U.S. Patent Nos. 6,135,117 (Campbell et al.) and 6,350,275 (Vreman et al.). These units have not yet been proven effective in large clinical trials.

SUMMARY

[0009] In one implementation, a light therapy apparatus is provided for delivering ocular light to a subject to treat disorders that are responsive to ocular light therapy. The apparatus includes a power supply and a hand-held light output device. The hand-held light output device includes a plurality of light sources powered by the power supply.

[0010] In another implementation, a method of light therapy is provided, wherein ocular light is administered to a subject to treat disorders that are responsive to ocular light therapy. The method includes delivering the light to the eyes of a subject by a hand-held light output device operated by a power supply.

BRIEF DESCRIPTION OF DRAWINGS

[0011] Figure 1 is a schematic diagram generalizing the light device of the present disclosure;

[0012] Figure 2 is an open-cover perspective view of one implementation of the light device of the present disclosure;

[0013] Figure 3 is a closed-cover perspective view of the implementation of Figure 1;

[0014] Figure 4 is a partial perspective view of the implementation of Figure 1;

[0015] Figure 5 is a partial side view of the implementation of Figure 4;

[0016] Figure 6 is a close-up partial side view of the view shown in Figure 5;

[0017] Figure 7 is a perspective view of another implementation of the light device of the present disclosure;

[0018] Figure 8 is a plan view of the implementation of Figure 7;

[0019] Figure 9 is a flow diagram showing one implementation of the light delivery method.

DETAILED DESCRIPTION

[0020] The light therapy device of the present disclosure delivers a full spectrum of light to the subject, while being fully portable and substantially avoiding eyestrain. In addition, the present light therapy device provides a process to make the necessary circadian rhythm adjustments in the subject's body suffering from jet lag by selectively applying the light based on the direction and extent of travel. The light therapy device of the present disclosure is also effective in treating other light-related problems, such as other circadian rhythm problems, seasonal affective disorders, some forms of depression, sleep disorders, and shift-work disorders, post- and ante-partum depression, pre-menstrual syndrome, late luteal phase dysphoric disorder (LLPDD), bulimia and eating disorders, and chronic fatigue.

[0021] The ocular light therapy devices of the present disclosure are not only portable, they are hand-held devices. As used here, the term "portable" shall be broadly understood to mean being capable of being easily transferred to different locations. Thus, typically a unit the size of a briefcase or smaller might be termed to be portable, even though it must be connected to a wall outlet power source at each location. There is also a category of devices referred to as "wearable," distinguished by being able to wear the device on the body, usually in close proximity to the eyes, such as on a visor. Wearable devices are further characterized by having a relatively low output, so that they are normally placed just a few inches from the eyes in order to be effective. As used here, the term "hand-held" refers to portable devices that are not wearable, that are capable of being powered by portable batteries, and that are relatively small – about 3 to 4 pounds or less and having dimensions in each direction of less than 10 inches.

[0022] Figure 1 is a generalized schematic diagram showing the elements of the hand-held light therapy device 10 according to the present disclosure. A light source 12 is driven by an inverter 14 which in turn is powered by a battery 16 or can also be powered by an AC adaptor connected to a standard power outlet. Battery 16 may be rechargeable and connected to a recharger 18 that in turn may connect to a conventional AC power outlet. Battery 16 also supplies power to a processor 20 that has two-way control and data communication with inverter 14. Data is provided by data input device 22. Processor 20 also provides a data and message display 24 and may also include integral timing functions. A timer 15 may also be connected between the battery 16 and the inverter 14, so that the device 10 may be manually actuated for a selected period of time.

[0023] It should be understood that the some elements of the system shown in Figure 1 are optional to the present implementation. The main elements include the battery power source 16 having an on-off switch, the battery 16 being coupled to the inverter 14 that activates the light source 12 providing therapeutic light. The other elements shown, such as the timer 15, processor 20, data input 22 and display 24 may be added, as desired.

[0024] Figures 2 and 3, show one implementation of a hand-held light therapy unit 30. Unit 30 is a battery powered, ocular, hand-held therapy device that incorporates a unique type of fluorescent light source referred to as cold cathode fluorescent lamps, referred to as CCFL. CCFL tubes are usually low pressure lamps, possibly using mercury vapor, and having a very small diameter (for example, 2 to 3 mm) and short length (for example, 50 to 700 mm).

[0025] CCFL tubes have been used to provide background lighting for laptop computers and to provide light for scanning and copying, because they provide an even distribution of light and can produce full-spectrum coloring and/or single-out specific wavelengths. See, e.g., "A Cold Cathode Fluorescent Lamp (CCFL) Controller Used in Magnetic Transformer Application," by Weiyun (Sophie) Chen, an article located on the internet at a web page having the address of <http://www.chipcenter.com/analog/c070.htm> (accessed June 6, 2003). Another application of CCFL tubes is shown in U.S. Patent No. 6,454,789 (Chen) where light is provided via fiber optics to treat tumors within a patient's body.

[0026] CCFL tubes are small and portable, and provide high efficiency in light output. They are also effective in providing a substantially full spectrum of light or an emphasis on a specific wavelength or range of wavelengths, thereby facilitating effective therapy. Unit 30 may be relatively small. For example, the unit may be about six inches in length by five inches wide by two inches thick. The device typically provides intensities of 2,500 lux, 5,000 lux and 10,000 lux, which are adequate for most light therapy applications. Consequently, it is readily portable and may be used in travel, at the bedside and in many situations where larger units would be too intrusive.

[0027] Referring to Figure 2, a light therapy unit 30 according to one implementation of the present disclosure is shown in an open position. A generally rectangular case 32 includes a recess 33 having a lens 34 therein. A light source 50 (shown in Figure 4) is disposed in the back portion 31 of case 32 behind the lens 34. Case 32 rests in an upright position on a base 36, held in place by a protrusion on the base (not shown). Below lens 34 is a display 38 for

depicting messages and data during use. On either side of display 38 are data input buttons 40-43 for providing data to the unit 30, as will be discussed in detail hereafter. Between the display 38 and the lens 34 are two buttons 44 and 45, for the on/off switch and other main menu selections.

[0028] When the unit 30 is not in use, it is placed in the closed position, as shown in Figure 3. Base 36 is hinged at end 46 so that it rotates approximately 270 degrees to form a cover 49 protecting lens 34 and the light sources behind it, as well as buttons 44 and 45, shown in Figure 2. With base 36 out of the way, unit 30 is configured to sit flat on back portion 31 as shown, with display 38 and buttons 40-43 on the top of the unit. This closed position not only protects the lens 34 and the light source 50, but also provides a slim, compact unit that is hand-held and can easily be stored or transported.

[0029] Looking at Figure 4, a light source 50 is shown. Six CCFL tubes 51 are placed in a generally parallel position relative to each other in recess 33 of case 32. A generally parabolic reflector 52 is positioned behind each of tubes 51 for directing light toward the front of the unit 30. Each tube 51 has electrical connections 53 and 54 extending from each end to connect to an inverter 60 (shown in Figure 5).

[0030] Figure 5 shows the light source 50 from a side view. Each of tubes 51 lies within the focal point of a parabolic portion 56 of reflector 52. Reflector 52 rests on a circuit board 58 to which the tubes 51 and reflector 52 are attached. On the underside of circuit board 58 is an inverter 60 and processor 62, corresponding to inverter 14 and processor 20 in Figure 1. Battery 64 is disposed just inside of case 32.

[0031] As shown in Figure 6, each tube 51 is disposed at the focal point of a respective parabolic portion 56 so that the rays of light 66 reflecting from the parabolic portion are directed out the front of unit 30 and towards the user to provide maximum reflectivity of the generated light.

[0032] The light therapy unit 30 may use multiple cold cathode fluorescent technology for the treatment of light related problems, such as circadian rhythm problems and mood and sleep disorders. The light therapy unit 30 described herein may provide long life (about 20,000 hours),

substantially full-spectrum color and high output over specific wavelengths, such as blue or green light wavelengths, while minimizing the presence of ultraviolet wavelengths. The device also may have a high CRI (Color Rendition Index), which is a measure of the trueness of color reflected when the light is exposed to a given color. In addition, the CCFL tubes of the present device may include one lead on each end. They may have a very small diameter, about the size of a plastic ink cylinder of a small writing pen.

[0033] The inverter 60 of the present device may include a unit with the ability to dim down and ramp up the light output from the light source. One embodiment includes a dimming/ramping function built into the inverter. The dimming function enables a dusk simulation to aid in falling asleep, and the ramping function allows for natural waking.

[0034] Contrary to most uses of CCFL tubes, the high-intensity inverter 60 of the present device is designed to run multiple CCFLs. This allows for fewer electronic components and thus lighter weight and smaller overall size of the unit.

[0035] The efficiencies of the CCFL technology allow the unit 30 to be battery-powered. The device is designed to run on a multi-current wall transformer 120 volts or 240 volts, plus or minus 20%. The unit 30 may also contain rechargeable batteries with a capacity to allow multiple therapy sessions.

[0036] The parabolic reflector unit 56 may be made of aluminum or other material which is 90% reflective or greater. The reflector material is bent in a parabolic shape that insures that the light emitted from the tubes 51 is reflected forward to the user.

[0037] The present device employs a very thin (1/16 inch) lens 34 which may be textured and made of clear acrylic. The diffraction of the light passing through the texture of the lens softens the high-intensity light and allows a more uniform treatment field. The acrylic properties of the lens 34 filter the ultraviolet rays so that the lens 34 will not yellow over time.

[0038] The CCFL tubes 51 may have a diameter of 2.2 mm and a length of 140 mm. The lamp voltage may be 340 volts with a wattage of 1.7

watts at 5mA rms and a tube current of 6 milliamps. The inverter 60 may have a strike voltage of 730 volts and a sustain voltage in the range of 325 – 450 volts. The inverter frequency can be 60 kilohertz. Ramping and dimming may be done through pulse width modulation (PWM) of the CCLF current. This PWM frequency is superimposed on the 60 khz current frequency, and averages 120 hz. By varying the duty cycle, the CCFL's can be dimmed by turning the current on and off at a sufficient rate to prevent the excitation of the lamp to decay, yet reduce the emissions.

[0039] Referring now to Figures 7 and 8, another implementation of the present disclosure is shown in the form of a hand-held light therapy unit 70. Unit 70 is an ocular therapy hand-held device that incorporates a light source using a matrix of LEDs 80, and capable of being battery-powered. Unit 70 comprises a casing 72 having a recess 74 for the matrix 80. A lens 76 is positioned in front of the matrix 80 to protect the source and to diffuse the intensity of the light. The light therapy unit 70 described herein may provide long life, substantially full-spectrum color and/or high output over specific wavelengths, such as blue or green light wavelengths, while minimizing the presence of ultraviolet wavelengths. The device also may have a high CRI (Color Rendition Index), which is a measure of the trueness of color reflected when the light is exposed to a given color. A fold-out stand 78 is position at the back of casing 72 to support unit 70 in an upright position. A circular button unit 77 provides buttons to activate the unit 70 and to operate a timer in the unit. Other buttons may be used for various functions, including activating various soothing sounds to accompany light therapy. A set of one or more lights 79 indicates whether the unit 70 is turned on and whether other functions have been activated.

[0040] Figure 8 shows a plan view of hand-held unit 70 with the lens 76 removed to more clearly show the matrix of LEDs 80. Matrix 80 is made up of 72 LEDs arranged in 6 rows and 12 columns. The LEDs may be 5 mm oval LEDs emitting a selected spectrum of visible light. The hand-held unit may be about 6 inches tall, 6 inches wide, and about 1 inch deep, weighing about 8.4

ounces. The light emission from light source 80 may fall in an effective range of 1,000 lux to 2,000 lux at 6 to 12 inches.

[0041] It should be understood that the light therapy unit 30 shown in Figures 2-6 and the light therapy unit 70 shown in Figures 7 and 8 are specific implementations of the generalized light therapy device 10 shown in Figure 1. For both implementations shown herein, the light therapy devices are made to be powered by a conventional internal or external battery pack. However, they may also be powered by an AC adaptor using standard wall-socket power.

[0042] The processor 20, shown in Figure 1, may include an atomic clock and a jet-lag calculator to help travelers to change their sleep patterns and circadian rhythms when they travel. The atomic clock may monitor time across time zones and display the time at the current location. The jet-lag calculator may advise a user, when traveling, about the times to use the device and the amount of light usage. The data may also advise the user when to avoid outdoor light.

[0043] Looking now at Figure 9, a flow diagram 90 is shown, describing a process that may be used by the processor 20, shown in Figure 1. The processor 20 may use an algorithm that accepts data input from a user. This data may include user data inputs 92 and travel data 94.

[0044] The software utilized by the processor 20 could be embedded in the processor 20 or could be downloaded by processor 20 from the internet or other external source, as needed.

[0045] Examples of data that is input to the processor 20 may include the departure airport, arrival airport, natural sleep time and natural wake time. It is known that, in order to achieve the best adjustments in the circadian rhythm, light should be administered relative to the time when the core body temperature is at a minimum. It is also known that, typically, the core body temperature minimum occurs about two hours before the natural wake up time.

[0046] The time to expose a subject to light also depends on whether the subject is traveling east-bound or west-bound. If the subject is eastbound, the circadian rhythm adjustment is best made if light is administered after the time when the core body temperature is at a minimum. If the subject is

westbound, the circadian rhythm adjustment is best made if light is administered before the time when the core body temperature is at a minimum.

[0047] Accordingly, the data to the processor may include the number of time zones traveled, the direction of travel, and the core-body temperature of the traveler. The process then determines at step 96 whether the traveler is headed east or west. It then uses either west-bound sleep and light schedules 98 and 100 or east-bound sleep and light schedules 102 and 104 to calculate a sleep/wake, light/dark regimen and instructions to facilitate the avoidance of jet lag problems. The digital display of the device provides function and text displays to provide the results of the jet-lag calculations.

[0048] The data input regarding a subject may also include data regarding whether the subject is "sleep delayed" or "sleep advanced." A sleep delayed subject tends to stay up later and have a more difficult time awakening in the morning, whereas a sleep advanced subject tends to want to go to bed earlier and get up earlier. This data could require separate west-bound and east-bound schedules, depending whether the subject was sleep delayed or sleep advanced.

[0049] In one implementation of the light therapy method, the user input is the natural wake up time and the natural fall-asleep time. From this data the processor calculates the time at which the core body temperature is expected to be at a minimum. The user then inputs the departure airport and the arrival airport. The processor calculates the number of time zones to travel and the direction of travel. The process then displays the regimen to follow for each day in order to administer the proper amount of high intensity light for a desired period of time and at the right time. Suggestions may also be given regarding when to go to bed and when to wake up.

[0050] The following is an example of implementing the above procedure:

User inputs:

Natural wake time = 7:00 am

Natural fall-asleep time = 11:00 pm

Processor calculates:

Time at which the core body temperature is at a minimum = 5:00 am

User inputs:

Departure Airport = Washington, DC

Arrival Airport = Paris, France

Processor calculates:

Number of time zones to travel = 6

Direction of travel = East

Number of days needed to shift sleep pattern = 3

Processor displays:

First day regimen = 6 am (East coast time) receive 10,000 lux light exposure,

0.5 hrs. (day before departure).

Second day regimen = 4 am (East coast time) receive 10,000 lux light exposure, 0.5 hrs. (departure day).

Third day regimen = 8 am (Paris time) 10,000 lux light exposure,

0.5 hrs. (day of arrival)

[0051] In addition, the present device can take into account the time when the traveler decides to start making adjustments to the circadian rhythm relative to the time that he begins traveling. For example, a traveler may prefer or be unable to start adjusting the circadian rhythm until arriving at his destination. In such case, the regimen required for making the circadian rhythm adjustment would be considerably different than if the adjust began before the day of travel. The processor in the current device can take the selected start time into account and make the appropriate adjustments in the calculations.

[0052] The foregoing discussion deals, by example only, with jet lag travel problems requiring circadian rhythm adjustments. Other types of circadian rhythm disorders or problems may also be effectively treated with the current light therapy device using appropriate data inputs and calculations. Further, the light therapy device may also be useful in treating other types of mood and sleep disorders that are usually responsive to light therapy, including but not limited to seasonal affective disorder, general depression, sleep disorders, and shift-work disorders, post- and ante-partum depression, pre-

menstral syndrome, late luteal phase dysphoric disorder (LLPDD), bulimia and eating disorders, and chronic fatigue.

[0053] Although the above embodiments are representative of the present invention, other embodiments will be apparent to those skilled in the art from a consideration of this specification and the appended claims, or from a practice of the embodiments of the disclosed invention. It is intended that the specification and embodiments therein be considered as exemplary only, with the present invention being defined by the claims and their equivalents.